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OCEANIC EXTREME MODEL ATMOSPHERES
FOR
AERO THERMODYNAMIC CALCULATIONS

by

Frank L. Martin

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In earlier papers (Model Atmospheres I and II), a procedure was developed for determining the most probable vertical temperature profile associated with the occurrence of 1% world-wide temperature extremes at mandatory-pressure levels, and at stations where such extremes are known to exist. The same technique based upon the use of the stepwise multiple regression analysis was employed in this study to determine vertically consistent atmospheres corresponding to known oceanic extremes. Cold open-

ocean extremes were found to exist up to 300 mb primarily near the Labrador coast at OSV "B", while the warm-open ocean extremes were found to exist in the vicinity of Majuro atoll of the Marshall Islands. The warmest of all sea-extremes for near-port conditions was found to exist in the Persian Gulf (near Station Bahrain). The stepwise multiple regression technique applied to the climatologically diverse set of locations of this study led to realistic estimates of the temperature profiles which were conditionally dependent upon the existence of 1% extreme forcing-level temperature T_J at previously designated pressure levels p_J.

ABSTRACT

In earlier papers (Model Atmospheres I and II), a procedure was developed for determining the most probable vertical temperature profile associated with the occurrence of 1% world-wide temperature extremes at mandatory-pressure levels, and at stations where such extremes are known to exist. The same technique based upon the use of the stepwise multiple regression analysis was employed in this study to determine vertically consistent atmospheres corresponding to known oceanic extremes. Cold open-ocean extremes were found to exist up to 300 mb primarily near the Labrador coast at OSV "B", while the warm-open ocean extremes were found to exist in the vicinity of Majuro atoll of the Marshall Islands. The warmest of all sea-extremes for near-port conditions was found to exist in the Persian Gulf (near Station Bahrain). The stepwise multiple regression technique applied to the climatologically diverse set of locations of this study led to realistic estimates of the temperature profiles which were conditionally dependent upon the existence of 1% extreme forcing-level temperature T_J at previously designated pressure levels p_J.

1. Introduction

In two earlier papers entitled "Development of regional extreme model atmospheres for use in aerothermodynamic calculations (I) and (II),"(henceforth to be abbreviated MA-I and MA-II, respectively), Martin (1972, 1973) developed a statistical technique for estimating the most probable temperature profile $T_M(p_M)$ consistent with the a priori existence of a 1% temperature extreme at any one of 8 specified mandatory pressure levels. The tentative 1% extremes for both the cold and warm cases are listed level by level in Table 1 (reproduced from MA-II). For each level, the station location associated with the particular temperature extreme has also been listed in Table 1.

TABLE 1. Locations of proposed extreme temperatures in the cold world-wide and warm world-wide cases (after Sissenwine, 1970). Some location and extreme-value modifications have been proposed in MIL-STD-210B (1973).

	Cold-Extreme				Warm-Extreme			
Level	Location	January Mean (°C)	STD. DEV. (°C)	1% Extreme (°C)	Location	July Mean (°C)	STD. DEV. (°C)	1% Extreme (°C)
SFC	Ojmjakon, USSR	-50.6	4.4	-60.6	Insalah, Algeria	40.9	3.9	49.0
850mb	Ojmjakon, USSR	-35.1	5.5	-47.0	Insalah, Algeria	28.9	2.2	34.0
700mb	Hall Beach, NWT	-27.3	6.5	-42.4	Baghdad, Iraq	17.0	2.2	22.1
500mb	Resolute, NWT	-43.0	4.6	-53.2	New Delhi, India	-4.3	3.9	4.0
300mb	Thule, Greenland	-60.6	2.2	-66.0	New Delhi, India	-25.8	3.9	-16.0
200mb	Thule, Greenland	-59.7	7.2	-75.0	Alert, NWT	-42.3	2.5	-36.5
150mb	Karachi, Pakistan	-65.0	6.0	-79.0	Alert, NWT	-43.3	2.5	-37.5
100mb	Singapore	-81.0	2.2	-86.0	Thule, Greenland	-43.8	2.2	-37.2

It should be noted that the tabular listings of the world-wide extremes, which appear in Table 1, as well as the suggested sites of these extremes were as

proposed in 1970 (Sissenwine, 1970). In later editions of the world-wide extreme-temperature values, for example in the 1973 version of MIL-STD-210B, a number of changes in the values of these extremes and of the locations at which they occur have been suggested. These revised extreme atmosphere listings have in general been based upon the research of Richard and Snelling (1971), and primarily affect the values and/or the locations of the listed warm extremes of Table 1 at both 300 and 200 mb.

It is not the purpose of the present paper to question the validity of the new extreme values. Suffice it to say that the present study was based upon rather sizeable data samples taken from 1967-70 for each station listed in Table 1. During this period, the radiosonde quality of the data-files provided by the National Climatic Center of Asheville, N. C., was at a very high standard. For example, the results displayed in Tables 3 through 14 of MA-II indicate that the standard deviation of temperature did not vary too greatly with pressure level. Furthermore, at each station considered in MA-I and MA-II, a large proportion of the radiosondes used in the full-sample (part (a)) statistics contained in these tables reached the 100 mb level. Each individual radiosonde which reached 100 mb was considered to have a higher credibility than one which terminated at 200 mb or below. In MA-I, II, extrapolation of temperature and thickness to the 100 mb was performed whenever the radiosonde reached the level p = 200 mb (Sec. 2 of MA-II, 1973). In summary, the data quality was uniformly good, and in addition the data-processing both by the staff at Asheville and at Monterey was well handled.

The immediate aim here is to restate the purpose of the earlier work and to extend the development techniques to Naval-air environments. The earliest purpose was to exploit more fully the inter-level correlations first noted by Cole and Nee (1965), and to extend by means of the stepwise regression technique the

specification of the temperature structure $T_M(p_M)$ at eight mandatory levels p_M at each station. Here T_M is to be specified in terms of the relevant temperature-predictors at other levels, including the "forcing-level p_J" for the given station, where p_J is the level known to correspond to either a world-wide or regional extreme.

The high values of the multiple correlation coefficients obtained by the specification procedure in both the full-sample sets and the 10% extreme-sets [parts (a) and (b)] of Tables 3 through 14 of MA-II are very reassuring. In addition, they afford convincing support of the predictability of the atmospheric temperature structure when some a priori condition concerning the forcing level p_J is assumed known.

2. The Naval-air Environment

(A) The cold extreme regions.

The Ocean Station Vessel observation program was being largely disbanded after 1970. However, the status of the oceanic radiosonde data files for the period 1967-70 was excellent. Hence it was decided to examine the latter files for statistical specification of $T_M(p_M)$-profiles over Ocean Station Vessels much as the regional extremes over continental areas had been treated (MA-I, II, 1973).

For guidance in locating the coldest oceanic regional extremes, reference was made to Crutcher (1973), who identified the coldest open ocean areas as existing over the North Atlantic Ocean up to 8 km (approximately 300 mb) in winter. Comparison of all available January 1967-70 radiosondes for the station vessel group B,A,C,I,J revealed that Ship "B" did indeed exhibit the coldest 1% extreme at the five forcing levels p_J listed below, whereas Ship "A" had the coldest 1% extreme at 200 mb. Hence temperature profiles consistent with the existence of a cold extreme at the following levels were taken under study. These levels were

$p_{J1} = 1000$ mb

$p_{J2} = 850$ mb

$p_{J3} = 700$ mb

$p_{J4} = 500$ mb

$p_{J5} = 300$ mb

$p_{J6} = 200$ mb (Ship "A")

The first five p_J-values were based upon the OSV Ship "B" reports. Hence these six forcing levels were used to generate $T_M(p_M)$-profiles at the set of eight mandatory levels contingent upon the existence of a cold extreme temperature $T(p_J)$.

Table 2 shows the arrangement of the sounding temperatures at Ships "A" and "B" by pressure levels p_k from $p_k = 1000$ mb to $p_k = 100$ mb, separated by uniform pressure increments of 50 mb (up to 200 mb). Above 200 mb the increment-size is reduced to 25 mb. The eight asterisked levels are used for denoting both the mandatory levels, and the individual forcing levels just set forth.

TABLE 2. Arrangements of sounding temperatures by pressure levels k=1,...,21 in each sounding. Asterisks denote the mandatory levels p_M for which temperature specifications have been developed.

	k = 1	2	3	4	5	k=6	
	1000mb*	950	900	850*	800	750	k = 6
k = 7	700*	650	600	550	500*	450	k = 12
k = 13	400	350	300*	250	200*	175	k = 18
k = 19	150*	125	100*				
	k = 19	20	21				

It is of interest to note that at the levels 150 and 100 mb, this station group had January temperatures considerably warmer than those considered in the world-wide extreme study [MA(I), MA(II)], so that forcing levels $p_J = 150$ and

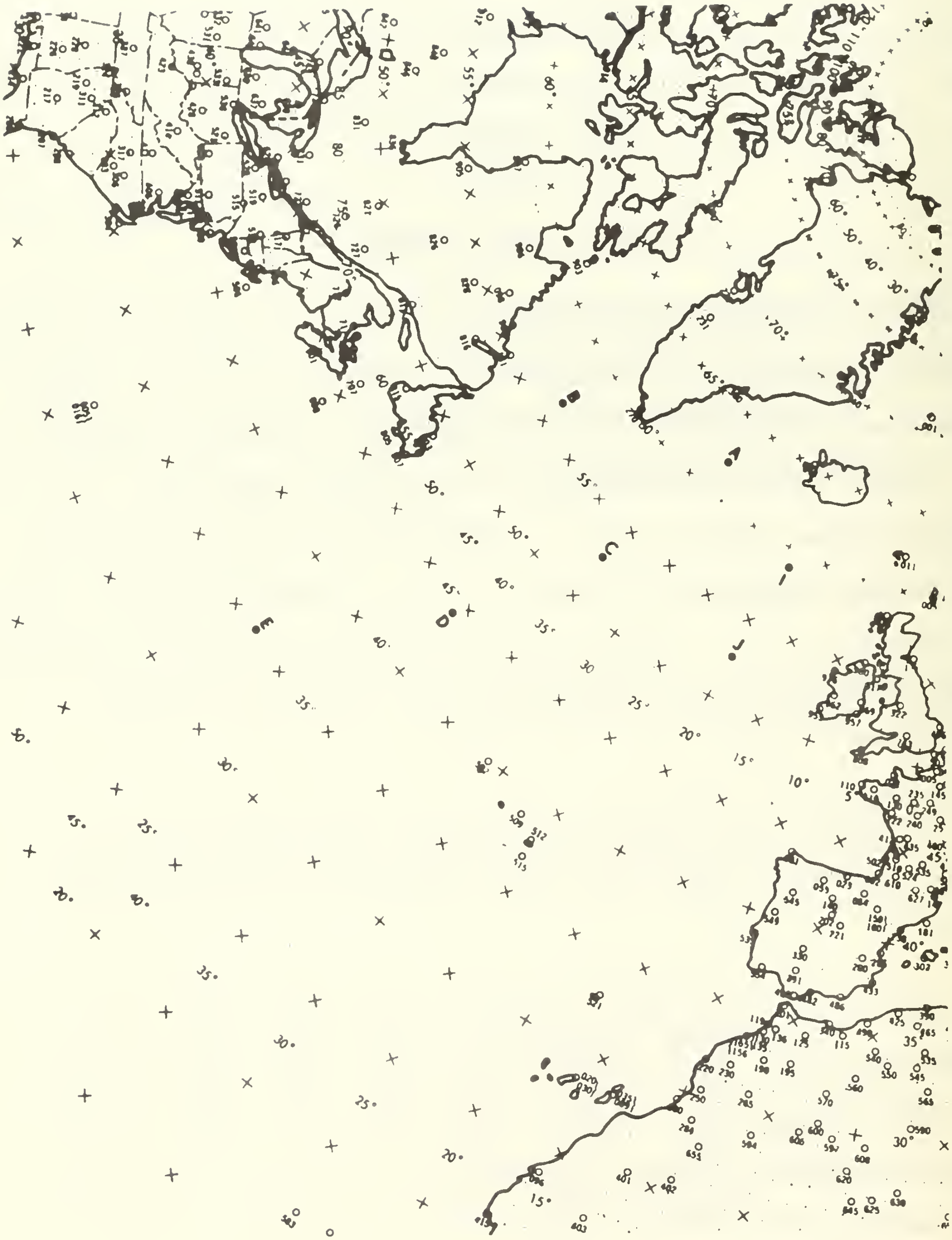

Fig. 1. Ocean Station Vessels tested for Naval-air open ocean cold extreme temperatures. Station "B" had the coldest 1% extreme of group B,A,I,C,J up to the 300 mb level. At 200 mb, the corresponding cold extreme of the group was located at Ship "A".

p_J = 100 mb were not considered for the development of contingent temperature profiles. As Crutcher (1973) has noted, the Naval environment extremes at these levels occur adjacent to Antarctica, which area was considered beyond the scope of this study.

Crutcher (1973) has also considered cold-extreme temperatures at port-locations in the Northern Hemisphere. Specifically he has identified open-port conditions at Point Barrow, Alaska. This was done primarily from the consideration of equipment withstanding periods, which involved only surface temperatures.

In this study, however, the open -port contingent-atmosphere has been considered to be a special and less extreme case of the set of world-wide extreme stations included in Table 1 for the case of the Northwest Territories of Canada, and of Ojmjakon, Siberia. Consequently winter-time open -port atmospheres have not been developed here.

2. (B) Naval-air warm extreme regions

Here again the work of Crutcher (1973) suggests the required locations for study in the Naval-air environment. Naval-air temperature profiles over three types of maritime surfaces are essentially the result of Crutcher's classification of maritime surface environments. These surface-extreme locations have been classified as follows:

(a) open ocean areas,

(b) localized sea areas, e.g. the Arabian Sea, and (more locally) the Persian Gulf,

(c) port locations.

(a) For shipboard warm extremes over open-ocean locations, Crutcher identifies the Marsden square locations 019 and 055 (see Fig. 2). For a detailed analysis of radiosonde data within area 019, the island radiosonde station of Majuro has been selected. This station was found to have a wealth

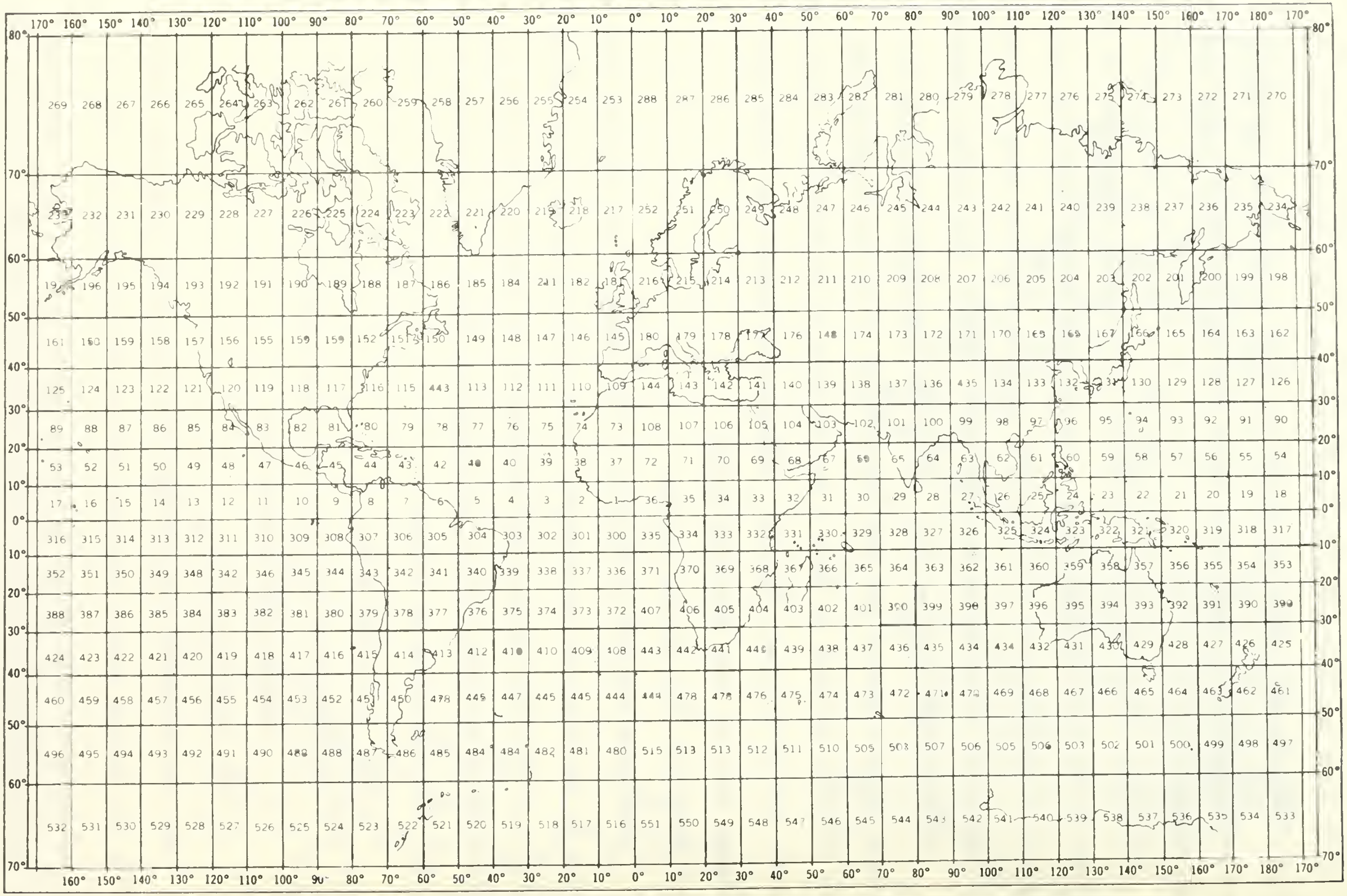

Fig. 2. Marsden square locations used to identify climatological-extreme features over the earth.

of radiosonde data during the summer periods of 1967-70.

(b) As representative of the more localized type of oceanic exposure (e.g., the southern edge of the Arabian Sea), the island station of Gan in Marsden square 328 has been selected for consideration of atmospheric temperature profiles $T_M(p_M)$ during July 1967-70. Both in this case and in case (a) above, the first forcing level[1] utilized was $p_J = p(Sfc)$, the results of which investigation showed that the Naval-air warm extreme environment was considerably cooler aloft than the corresponding world-wide warm extreme cases considered in MA-II (1973). Furthermore, the standard deviations of temperature were quite small level for level, so that the temperature structure $T_M(p_M)$ differed little regardless of which forcing level $p_J \geq 200$ mb was selected. In this study, the only statistical results displayed are those corresponding to the forcing level $p_J = p(Sfc)$.

(c) The warm-temperature extreme port location cited by Crutcher (1973) is Abadan, Iran, at the north end of the Persian Gulf. Here a 1% warm-extreme $T_J(Sfc) = 48C$ may be expected in July according to MIL-STD-210B (1973). However, no radiosonde file exists for Abadan, and only a very fragmentary radiosonde file exists for nearby Kuwait Airport, where the surface temperatures are not necessarily as high as at Abadan.

To provide an alternative record, we have selected the port of Bahrain, Arabia, located on a peninsula projecting into the Persian Gulf. This station has a detailed radiosonde record during the summer periods of 1967-70. The surface temperature is not as warm at Bahrain (Table 12) as that at Abadan, since it is moderated by the less extreme temperatures of the Gulf. However, presumably a surface warm extreme at Bahrain would be highly correlated with a

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[1]Note that p(Sfc) has been listed for simplicity in Tables 10, 11 and 12 as p = 1000 mb, regardless of the actual surface pressure at these locations.

corresponding (higher) extreme at Abadan. Consequently, Bahrain summer data has been studied for the purpose of developing profiles $T_M(p_M)$ consistent with the occurrence of warm-extreme surface temperatures at this general location, in the absence of radiosonde data from Abadan.

2. (C) Summary of stations studied for Naval-air warm extreme cases

Fig. 3 shows the locations of the three stations just described in 2(B). Each station has been found to be characterized by radiosonde data of good quality. For purposes of the determination of a warm-extreme surface temperature at the three stations, the data-period was lengthened to June-August in the years 1967-70. This served to give a sizeable increase in the radiosonde samples without diminishing the probability of an extreme.

Note that the enhancement of the data period to include three months in each data year led to no inconsistencies in that the standard deviation of the temperature at mandatory levels was not appreciably changed from the four-year July-only sample.

In summary, the data sources for the Naval-air warm-extreme locations have been taken from the June-August 1967-70 radiosonde files corresponding to the stations

(a)	Majuro	$07^\circ05'$N,	$171^\circ23'$E
(b)	Gan	$00^\circ41'$S,	$73^\circ09'$E
(c)	Bahrain	$26^\circ16'$N,	$50^\circ37'$E

These stations were considered to be typical of Naval-air warm-extreme environment over (a) the open-ocean, (b) the somewhat more protected tropical seas, and (c) a tropical port or nearby area (see Fig. 3).

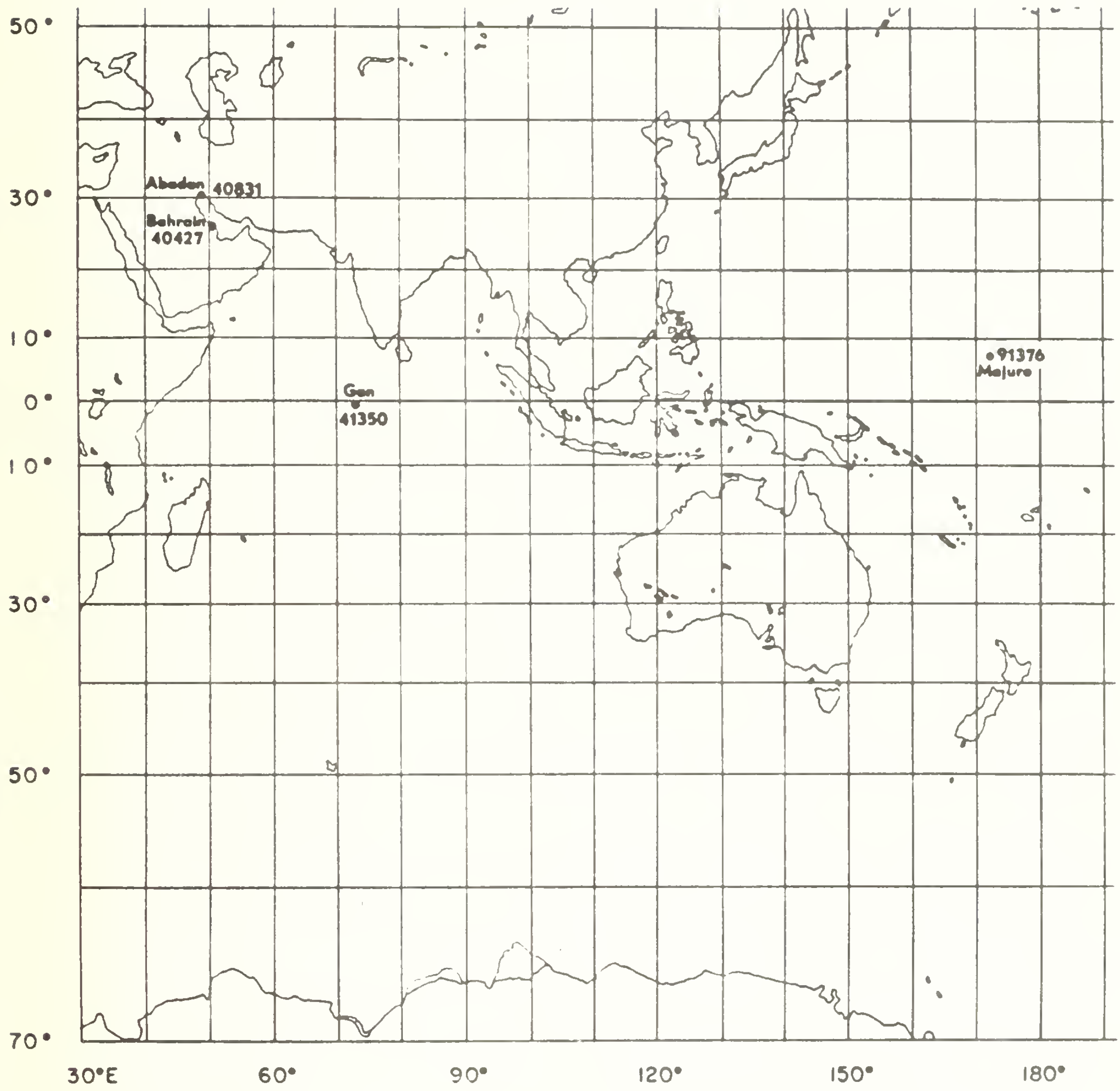

Fig. 3. Summary of stations studied for Naval-air warm surface extremes. Majuro is representative of open ocean conditions; Gan is considered representative of a more localized sea condition such as the Arabian Sea. Bahrain typifies a port extreme such as exists at Abadan, Iran.

3. Regression-generated temperature profiles $T_M(p_M)$

(A) January-extreme profiles

Here the method employed in Section 3 of MA-II (1973) was followed and will not be repeated in detail. The results of the statistical analysis for each station (essentially OSV "B" and "A") and forcing levels p_J, are listed in tabular form in Tables 3,..,8. The forcing levels involved are p_J = 1000, 850, 700, 500, 300 and 200 mb in sequence.

The resulting statistical analyses are based essentially upon use of the regression procedure to derive $T_M(p_M)$ profiles corresponding to (a) the full-sample of T_J-data, (b) the 10% nominal extreme sample, and (c) the 1% subsample extreme of T_J-values. A nominal extreme may be defined for each station and T_J according to the Gaussian probability percentiles

$$
\begin{aligned}
T_{.10}(p_J) &= \bar{T}_J \pm 1.2817\ \sigma_J \\
T_{.01}(p_J) &= \bar{T}_J \pm 2.3267\ \sigma_J
\end{aligned}
\qquad (1)
$$

Here the minus sign applies for the cold extreme. Values of $\bar{T}_J, \sigma_J$ are taken from the full-sample analyses in part (a) of each table. In each of the tabular sections a,b is shown also the regression statistics R and σ_E, where

R is the multiple correlation coefficient

and

$$\sigma_E = \sigma_J \sqrt{1 - R^2}$$

Here σ_E is the standard error, after application of the specification equation for T_M. In the Tables 3,...,8, the values of the multiple correlation coefficients R in each tabular section a,b, are generally in excess of .97 in the specification of T_M-profiles.

TABLE 3. Regression statistics at mandatory pressure levels at OSV "B", using $T_J = T(1000)$ as the forcing level January temperature. Part (a) refers to the full-data-January sample; part (b) refers to the nominal 10% cold extreme sample of $T_J(1000)$; part (c) lists the sounding-level mean temperatures corresponding to the 1% extreme cold set of $T_J(1000)$.

Level (mb)	(a) N = 185 cases				(b) N = 26 cases, $T_{.10} = -4.4°C$				(c) N = 5
	Mean °C	Std. Dev. °C	Mult. Corr. Coeff.	Std. Err. of Est. °C	Mean °C	Std. Dev. °C	Mult. Corr. Coeff.	Std. Err. of Est. °C	Temp-Means, °C $\bar{T}_J < T_J(1000)$, -7.7°C
1000	-.41	3.134	-	-	-5.79	1.246	-	-	-7.80
850	-9.18	5.275	.9881	.829	-16.58	2.647	.9465	.891	-19.60
700	-16.55	5.861	.9924	.731	-22.83	6.145	.9958	.571	-26.82
500	-31.74	5.592	.9954	.548	-34.80	7.198	.9950	.746	-37.45
300	-53.52	4.005	.9403	1.394	-54.04	2.606	.8735	1.323	-50.72
200	-54.41	5.672	.9686	1.442	-54.39	4.703	.9690	1.212	-49.55
150	-53.64	4.701	.9779	1.000	-53.69	4.745	.9896	.712	-49.22
100	-55.82	5.263	.9599	1.508	-55.97	6.636	.9671	1.761	-50.82

TABLE 4. Regression statistics at mandatory pressure levels at OSV "B" , using $T_J = T(850)$ as the forcing level January temperature. Part (a) refers to the full-data-January sample; part (b) refers to the nominal 10% cold extreme sample of $T_J(850)$; part (c) lists the sounding-level mean temperatures corresponding to the 1% extreme cold set of $T_J(850)$.

Level (mb)	(a) N = 185 cases				(b) N = 22 cases, $T_{.10} = -15.9$				(c) N = 3
	Mean °C	Std. Dev. °C	Mult. Corr. Coeff.	Std. Err. of Est. °C	Mean °C	Std. Dev. °C	Mult. Corr. Coeff.	Std. Err. of Est. °C	Temp-Means, °C $\bar{T}_J < T_J(850)$, $-21.45°C$
1000	-.41	3.134	.9675	.809	-5.70	1.480	.8968	.688	-7.8
850	-9.18	5.275	-	-	-17.71	1.394	-	-	-20.03*
700	-16.55	5.861	.9925	.731	-24.45	4.867	.9969	.404	-28.97
500	-31.74	5.592	.9954	.548	-36.75	5.807	.9905	.838	-39.65
300	-53.52	4.005	.9409	1.387	-54.51	2.552	.8662	1.341	-52.97
200	-54.41	5.672	.9680	1.455	-53.17	4.696	.9740	1.118	-52.73
150	-53.64	4.701	.9779	1.006	-53.21	5.375	.9846	.963	-53.20
100	-55.82	5.263	.9601	1.506	-56.20	7.096	.9824	1.395	-55.57

TABLE 5. Regression statistics at mandatory pressure levels at OSV "B" , using $T_J = T(700)$ as the forcing level January temperature. Part (a) refers to the full-data-January sample; part (b) refers to the nominal 10% cold extreme sample of $T_J(700)$; part (c) lists the sounding-level mean temperatures corresponding to the 1% extreme cold set of $T_J(700)$.

Level (mb)	(a) N = 185 cases				(b) N = 15 cases, $T_{.10} = -24.0^{\circ}C$				(c) N = 3
	Mean $^{\circ}C$	Std. Dev. $^{\circ}C$	Mult. Corr. Coeff.	Std. Err. of Est. $^{\circ}C$	Mean $^{\circ}C$	Std. Dev. $^{\circ}C$	Mult. Corr. Coeff.	Std. Err. of Est. $^{\circ}C$	Temp-Means, $^{\circ}C$ $\bar{T}_J < T_J(700)$, $-30.1^{\circ}C$
1000	-.41	3.134	.9678	.807	-5.33	2.207	.9680	.598	-6.50
850	-9.18	5.275	.9881	.830	-17.32	2.449	.9936	.299	-19.10
700	-16.55	5.861	-	-	-27.85	2.504	-	-	-30.20
500	-31.75	5.592	.9954	.548	-39.92	4.192	.9853	.774	-41.80
300	-53.52	4.005	.9408	1.388	-54.17	3.194	.9400	1.443	-55.47
200	-54.41	5.672	.9680	1.455	-53.44	5.074	.9837	.986	-55.37
150	-53.64	4.701	.9780	1.003	-54.07	6.121	.9913	.869	-56.90
100	-55.82	5.263	.9599	1.508	-57.13	8.183	.9768	1.895	-61.57

TABLE 6. Regression statistics at mandatory pressure levels at OSV "B" , using $T_J = T(500)$ as the forcing level January temperature. Part (a) refers to the full-data-January sample; part (b) refers to the nominal 10% cold extreme sample of $T_J(500)$; part (c) lists the sounding-level mean temperatures corresponding to the 1% extreme cold set of $T_J(500)$.

Level (mb)	(a) N = 185 cases				(b) N = 18 cases, $T_{.10} = -38.9^{\circ}C$				(c) N = 2
	Mean °C	Std. Dev. °C	Mult. Corr. Coeff.	Std. Err. of Est. °C	Mean °C	Std. Dev. °C	Mult. Corr. Coeff.	Std. Err. of Est. °C	Temp-Means, °C $\bar{T}_J < T_J(500)$, $-44.7^{\circ}C$
1000	-.409	3.134	.9678	.806	-3.19	3.084	.9757	.719	-4.60
850	-9.18	5.275	.9882	.827	-14.14	4.149	.9965	.370	-17.95
700	-16.55	5.861	.9925	.731	-25.27	4.042	.9959	.391	-30.20
500	-31.74	5.592	-	-	-41.32	1.774	-	-	-44.70
300	-53.52	4.005	.9410	1.385	-53.19	3.760	.9489	1.263	-56.40
200	-54.41	5.672	.9682	1.452	-52.48	5.081	.9905	.745	-58.90
150	-53.64	4.701	.9782	.998	-53.92	5.764	.9920	.776	-61.30
100	-55.82	5.263	.9598	1.509	-56.49	8.161	.9817	1.646	-66.50

TABLE 7. Regression statistics at mandatory pressure levels at OSV "B" , using $T_J = T(300)$ as the forcing level January temperature. Part (a) refers to the full-data-January sample; part (b) refers to the nominal 10% cold extreme sample of $T_J(300)$; part (c) lists the sounding-level mean temperatures corresponding to the 1% extreme cold set of $T_J(300)$.

Level (mb)	(a) N = cases				(b) N = 18 cases, $T_{.10}$=-58.6°C				(c) N = 2
	Mean °C	Std. Dev. °C	Mult. Corr. Coeff.	Std. Err. of Est. °C	Mean °C	Std. Dev. °C	Mult. Corr. Coeff.	Std. Err. of Est. °C	Temp-Means, °C $\bar{T}_J < T_J(300)$, -62.8°C
1000	-.41	3.134	.9675	.809	.81	2.048	.9626	.591	-.45
850	-9.182	5.275	.9882	.826	-8.23	3.224	.9608	.952	-9.95
700	-16.554	5.861	.9925	.732	-16.53	3.895	.9666	1.029	-19.50
500	-31.745	5.592	.9954	.548	-32.78	2.555	.9838	.487	-35.65
300	-53.524	4.005	-	-	-59.73	0.925	-	-	-61.5*
200	-54.410	5.672	.9682	1.452	-58.505	4.805	.9739	1.160	-62.1
150	-53.636	4.701	.9779	.999	-57.778	5.538	.9903	.819	-63.35
100	-55.815	5.263	.9599	1.509	-59.133	6.104	.9861	1.081	-65.4

TABLE 8. Regression statistics at mandatory pressure levels at OSV "A" , using $T_J = T(200)$ as the forcing level January temperature. Part (a) refers to the full-data-January sample; part (b) refers to the nominal 10% cold extreme sample of $T_J(200)$; part (c) lists the sounding-level mean temperatures corresponding to the 1% extreme cold set of $T_J(200)$.

Level (mb)	(a) N = 200 cases				(b) N = 25 cases, $T_{.10} = -65.7^{o}C$				(c) N = 2
	Mean ^{o}C	Std. Dev. ^{o}C	Mult. Corr. Coeff.	Std. Err. of Est. ^{o}C	Mean ^{o}C	Std. Dev. ^{o}C	Mult. Corr. Coeff.	Std. Err. of Est. ^{o}C	Temp-Means, ^{o}C $\bar{T}_J < T_J(200)$, $-71.7^{o}C$
1000	3.44	2.792	.9998	.053	3.64	2.548	.9997	.067	2.0
850	-6.18	4.842	.9801	.981	-5.16	4.696	.9609	1.358	-2.0
700	-13.91	5.248	.9999	.022	-10.36	4.212	.9999	.019	-12.5
500	-30.13	5.240	.9997	.122	-26.04	3.007	.9999	.048	-22.0
300	-52.49	3.748	.9998	.070	-52.96	2.776	.9996	.084	-54.5
200	-56.59	7.145	-	-	-68.68	2.393	-	-	-74.5
150	-55.53	5.962	.9999	.048	-63.96	4.677	.9999	.040	-67.67
100	-57.65	6.321	.9838	1.140	-64.84	4.239	.9953	.430	-69.00

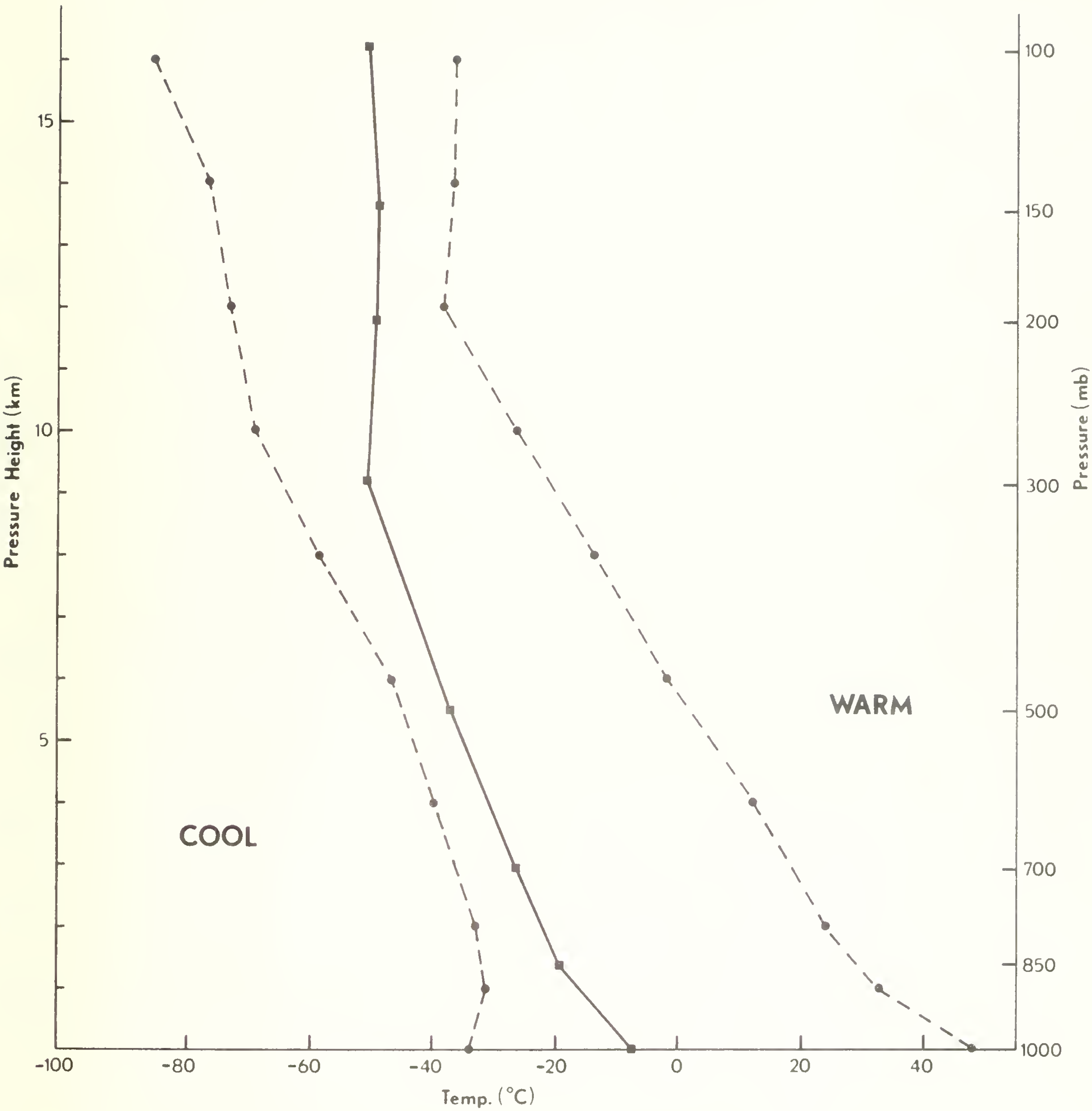

Fig. 4. Regression-generated January temperature profile (solid curve) at OSV "B" corresponding to the 1% extreme-cold forcing-level temperatures T_J(Sfc) at the surface. The COOL and WARM profiles (dashed) are based on the level-by-level 1% Naval-air extremes listed in MIL-STD-210B (1973).

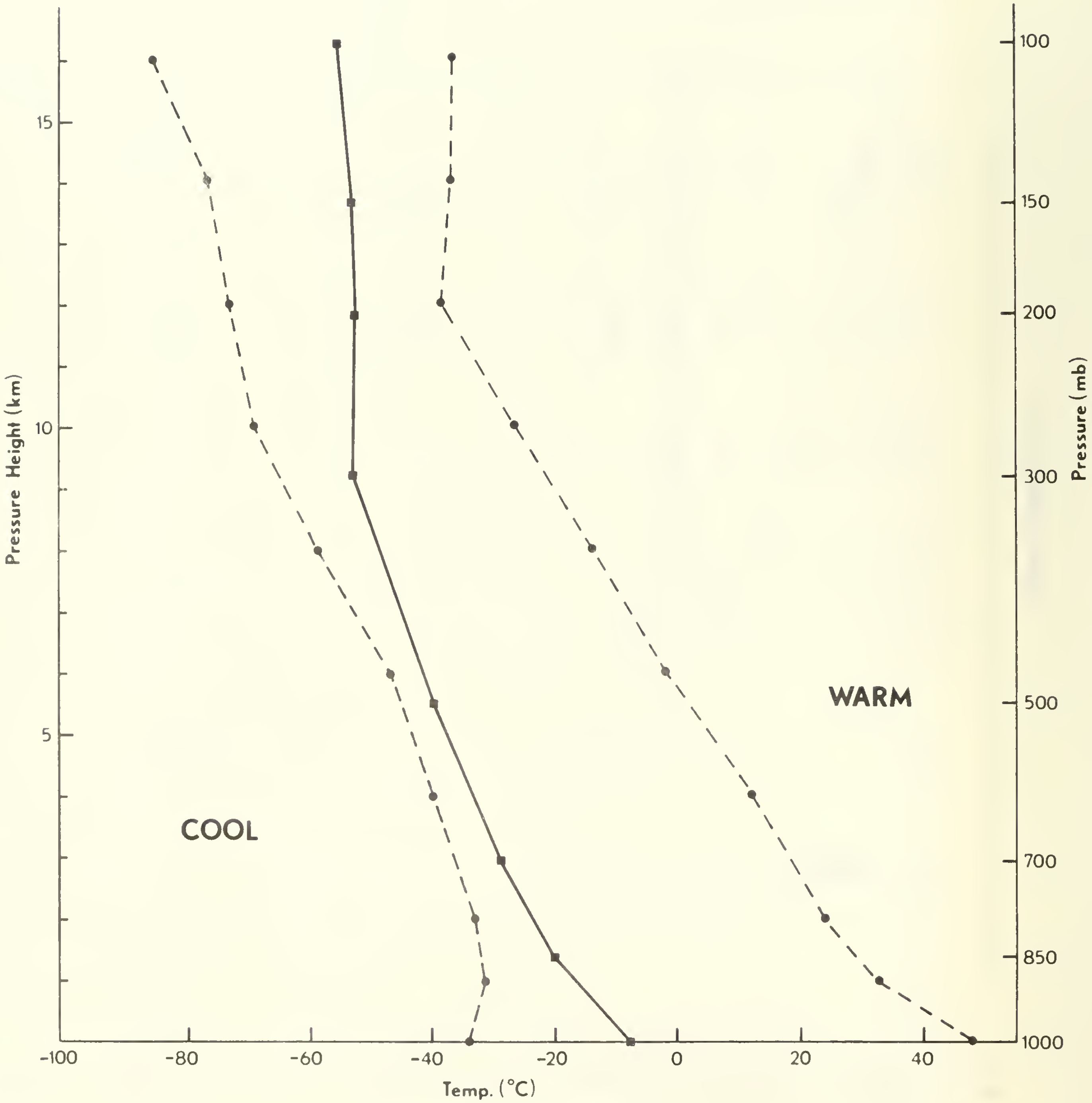

Fig. 5. Regression-generated January temperature profile (solid curve) at OSV "B" corresponding to the 1% extreme-cold forcing-level temperatures $T_J(850)$ at 850 mb. The COOL and WARM profiles (dashed) are based on the level-by-level 1% Naval-air extremes listed in MIL-STD-210B (1973).

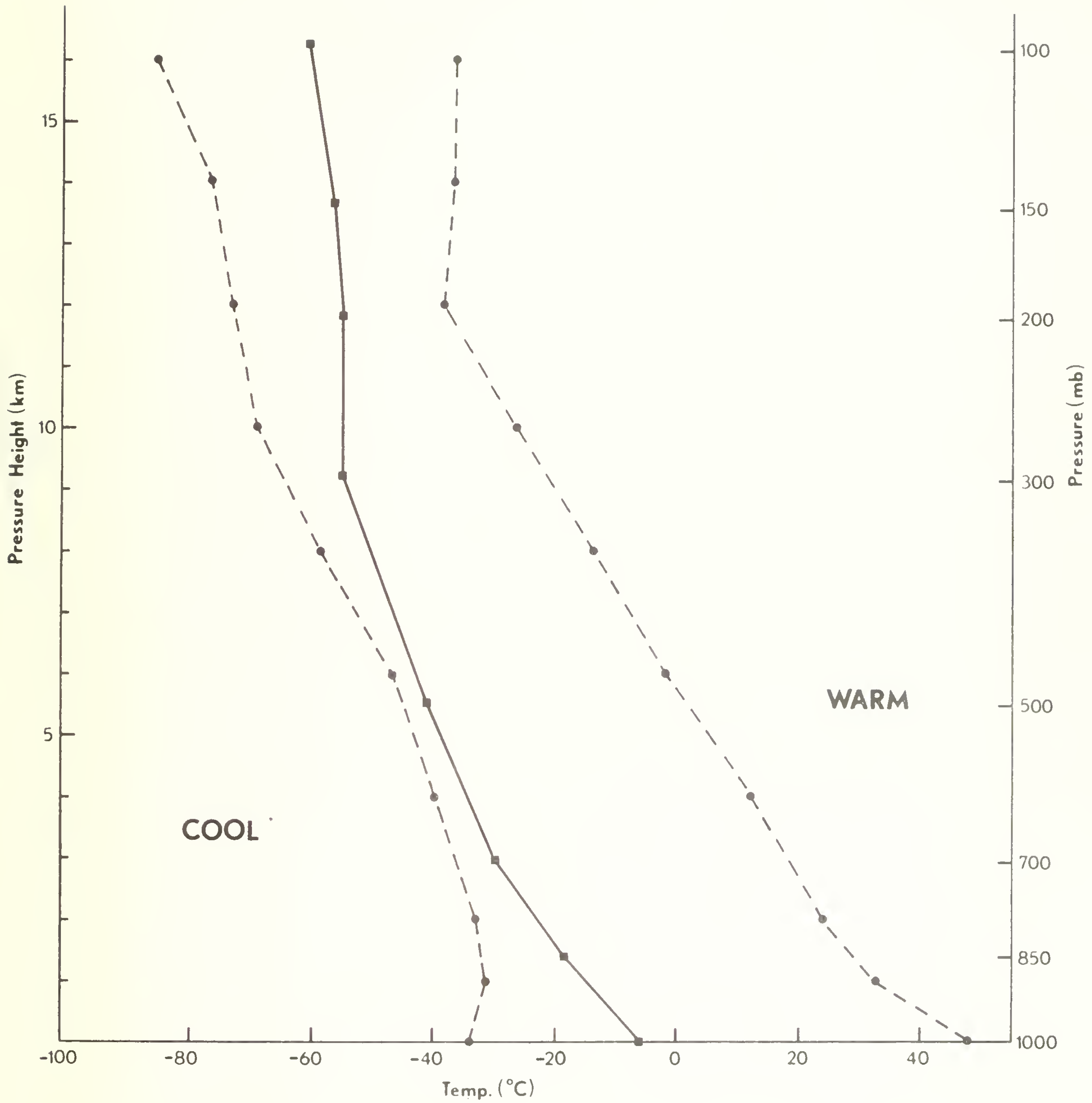

Fig. 6. Regression-generated January temperature profile (solid curve) at OSV "B" corresponding to the 1% extreme-cold forcing-level temperatures $T_J(700)$ at 700 mb. The COOL and WARM profiles (dashed) are based on the level-by-level 1% Naval-air extremes listed in MIL-STD-210B (1973).

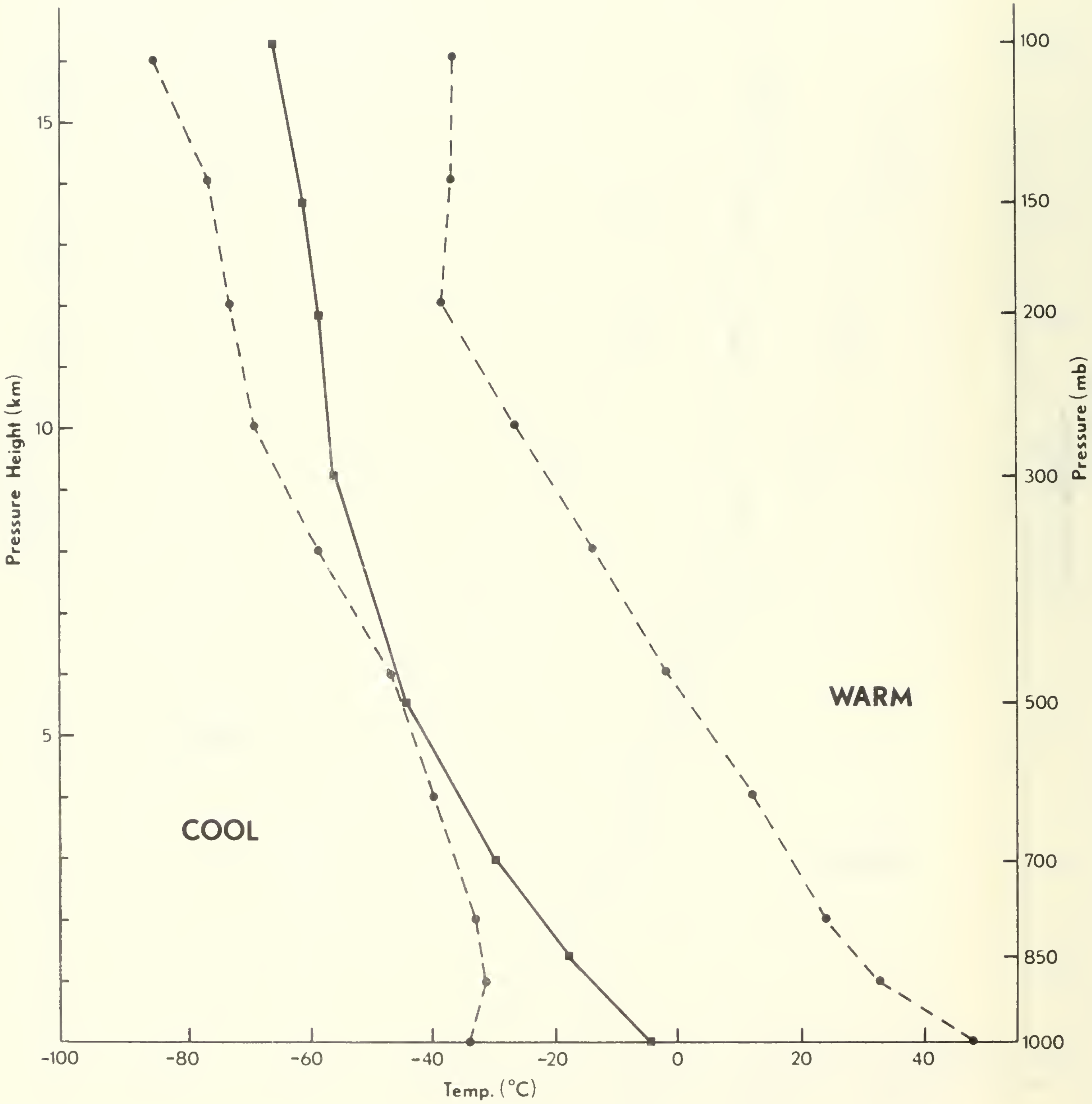

Fig. 7. Regression-generated January temperature profile (solid curve) at OSV "B" corresponding to the 1% extreme-cold forcing-level temperatures $T_J(500)$ at 500 mb. The COOL and WARM profiles (dashed) are based on the level-by-level 1% Naval-air extremes listed in MIL-STD-210B (1973).

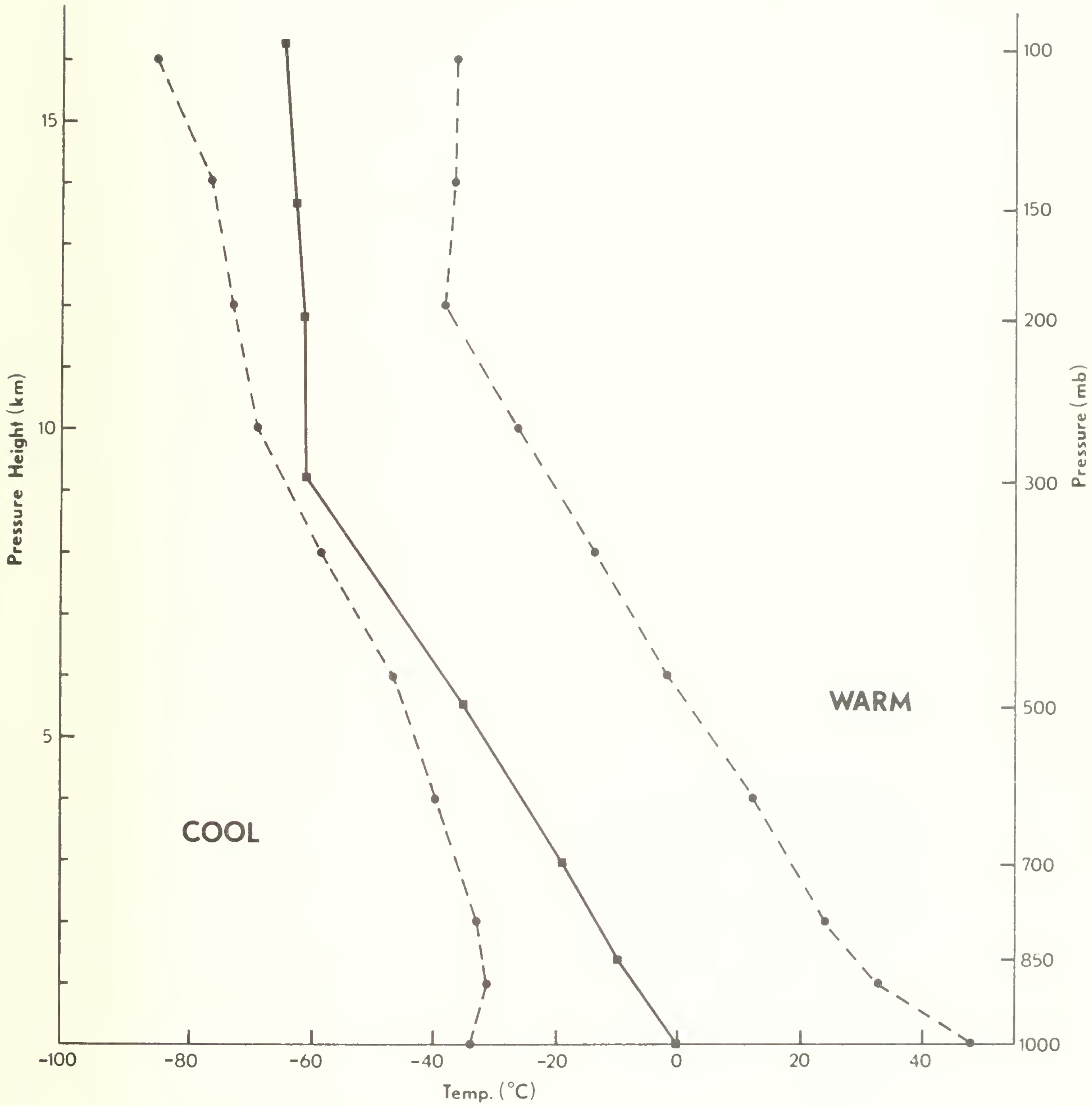

Fig. 8. Regression-generated January temperature profile (solid curve) at OSV "B" corresponding to the 1% extreme-cold forcing-level temperatures $T_J(300)$ at 300 mb. The COOL and WARM profiles (dashed) are based on the level-by-level 1% Naval-air extremes listed in MIL-STD-210B (1973).

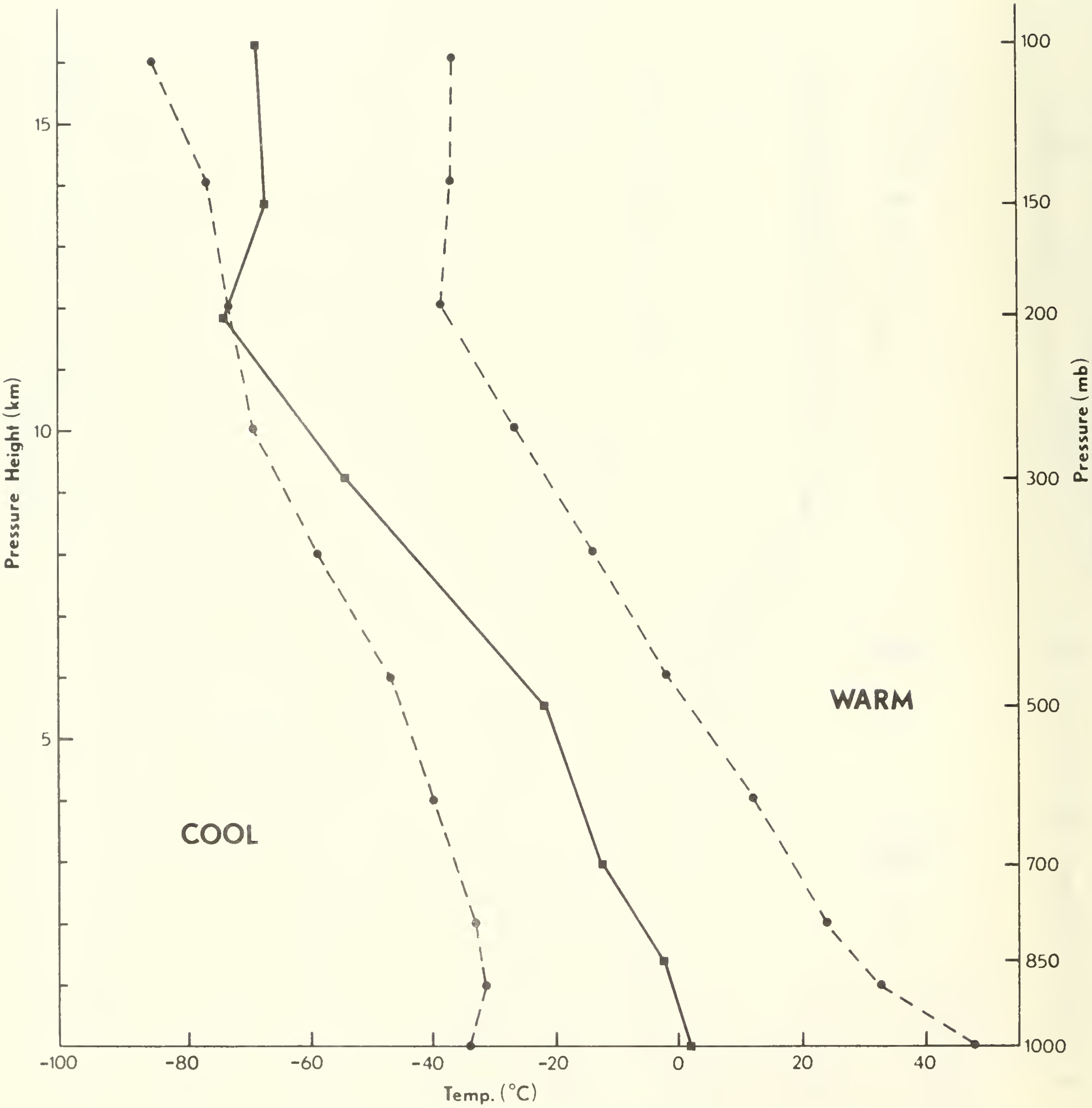

Fig. 9. Regression-generated January temperature profile (solid curve) at OSV "A" corresponding to the 1% extreme-cold forcing-level temperatures $T_J(200)$ at 200 mb. The COOL and WARM profiles (dashed) are based on the level-by-level 1% Naval-air extremes listed in MIL-STD-210B (1973).

It is to be noted that in Tables 3,4,...,8 there is little systematic deviation in the standard errors resulting from treatment (b) relative to that for the full-sample treatment (a). These results give credibility to the requirement of a meaningful forcing-level temperature T_J.

An asterisk in tabular section (c) of Tables 3,...,8 indicates that the 1% extreme-value of the T_J-observation used for the forcing condition was not as cold as that calculated by Eq. 1, which value appears in the section (c) tabular-heading.

The $T_M(p_M)$ profiles of Tables 3,...,8 have been graphed in Figs. 4,...,9, respectively against pressure and/or pressure-altitude in the vertical. For comparison purposes, the level-by-level 1% Naval-air cold extreme temperatures have been extracted from MIL-STD-210B (1973, p. 23) and plotted on each figure. Likewise the Naval-air warm extreme temperatures as taken from p. 22 of the same source have been plotted on each figure to show the opposite operational extreme.

It should be noted that the Naval air surface cold extreme of MIL-STD-210B is representative of port conditions with nearby continental conditions whereas our surface extreme (Fig. 4) applies to the open ocean.

3. (B) Warm-extreme profiles

It is of interest here to compare the warm-extreme temperature envelope (dashed line) which appears on the right side of each of Figs. 4,...,12. As already noted, Crutcher (1973) ascribes the location of the warmest temperatures (to about 12 km) to the Arabian Sea. Actually, a

comparison of our Bahrain "forced" T_M-profile (Table 11, Fig. 12), using a forcing level T_J(Sfc), with the MIL-STD-210B Naval-air warm-extreme temperatures shows a close approximation to the latter extreme values up to 300 mb. The close comparison between Crutcher's (1973) warm extremes to 10 km and those listed here for Bahrain suggest that the warmest area in the lowest 10 km over the northern Arabian Sea and our test-area in the Persian Gulf are essentially indistinguishable (except for the Abadan port-maximum). On the other hand, Gan's extreme temperature profile $T_M(p_M)$ resulting from surface-level warm-extreme forcing is somewhat cooler level-for-level than that at Bahrain.

It should be noted that the $T_M(p_M)$-profiles in Figs. 10,11,12 at $p \leqq 200$ mb are all much colder than the MIL-STD-210B Naval-air warm extremes. The latter correspond to geographic areas near the Aleutian Islands at 60N according to Crutcher (1973). Actually the extreme-warm values listed by Crutcher at 12, 14 and 16 km are very nearly identical to the values derived in MA-I for the corresponding pressure-altitudes at Alert and Thule.

In summary, the Bahrain $T_M(p_M)$ profile derived with surface-forcing closely approximates the MIL-STD-210B at all levels to 300 mb. At 200 mb and above, the contingent Naval-air $T_M(p_M)$ warm profiles conform most closely to those North American Arctic cases discussed in Model Atmospheres-I (1972) corresponding to warm-extreme cases for Alert $T_J(200)$, Alert $T_J(150)$, and Thule $T_J(100)$.

TABLE 9. Regression statistics at mandatory pressure levels at Majuro , using $T_J = T(1000)$ as the forcing level July temperature. Part (a) refers to the full-data-July sample; part (b) refers to the nominal 10% warm extreme sample of $T_J(1000)$; part (c) lists the sounding-level mean temperatures corresponding to the 1% extreme warm set of $T_J(1000)$.

Level (mb)	(a) N = 379 cases				(b) N = 30 cases, $T_{.10} = 27.7^{\circ}C$				(c) N = 5
	Mean $^{\circ}C$	Std. Dev. $^{\circ}C$	Mult. Corr. Coeff.	Std. Err. of Est. $^{\circ}C$	Mean $^{\circ}C$	Std. Dev. $^{\circ}C$	Mult. Corr. Coeff.	Std. Err. of Est. $^{\circ}C$	Temp-Means, $^{\circ}C$ $\bar{T}_J > T_J(1000)$, $28.8^{\circ}C$
1000	26.57	1.067	-	-	27.89	.678	-	-	28.80
850	17.88	.894	.8385	.492	18.14	.730	.7814	.472	18.55
700	9.69	1.067	.8892	.493	9.91	.814	.9058	.357	10.02
500	-5.33	1.088	.8054	.652	-5.06	.871	.7363	.611	-5.16
300	-30.47	1.398	.8954	.629	-30.17	1.085	.8658	.562	-29.28
200	-53.12	1.280	.8733	.630	-52.36	1.119	.8965	.514	-51.6
150	-67.48	1.642	.8063	.982	-66.84	.904	.7500	.620	-66.36
100	-77.37	2.865	.3896	2.667	-76.06	2.440	.2727	2.433	-77.36

TABLE 10. Regression statistics at mandatory pressure levels at Gan (Maldive Is), using $T_J = T(1000)$ as the forcing level July temperature. Part (a) refers to the full-data-July sample; part (b) refers to the nominal 10% warm extreme sample of $T_J(1000)$; part (c) lists the sounding-level mean temperatures corresponding to the 1% extreme warm set of $T_J(1000)$.

Level (mb)	(a) N = 157 cases				(b) N = 10 cases, $T_{.10} = 28.8^{\circ}C$				(c) N = 2
	Mean $^{\circ}C$	Std. Dev. $^{\circ}C$	Mult. Corr. Coeff.	Std. Err. of Est. $^{\circ}C$	Mean $^{\circ}C$	Std. Dev. $^{\circ}C$	Mult. Corr. Coeff.	Std. Err. of Est. $^{\circ}C$	Temp-Means, $^{\circ}C$ $\bar{T}_J > T_J(1000)$, $30.1^{\circ}C$
1000	27.26	1.239	-	-	29.46	.985	-	-	30.90
850	17.27	1.051	.9181	.428	18.24	1.001	.9268	.426	17.70
700	8.77	1.070	.9186	.434	9.50	1.418	.9608	.446	8.80
500	-6.50	1.224	.9360	.442	-5.93	1.917	.9359	.766	-6.55
300	-32.65	1.316	.8813	.639	-32.17	1.466	.9413	.561	-31.75
200	-55.44	1.599	.9483	.521	-55.25	1.611	.9635	.489	-57.05
150	-69.27	2.418	.9290	.919	-69.01	2.342	.8872	1.225	-68.85
100	-76.45	3.382	.5266	2.952	-78.13	4.109	.8735	2.268	-77.65

TABLE 11. Regression statistics at mandatory pressure levels at Bahrain, Arabia, using $T_J = T(1000)$ as the forcing level July temperature. Part (a) refers to the full-data-July sample; part (b) refers to the nominal 10% warm extreme sample of $T_J(1000)$; part (c) lists the sounding-level mean temperatures corresponding to the 1% extreme warm set of $T_J(1000)$.

Level (mb)	(a) N = 196 cases				(b) N = 20 cases, $T_{.10}=38.6^{\circ}C$				(c) N = 3
	Mean $^{\circ}C$	Std. Dev. $^{\circ}C$	Mult. Corr. Coeff.	Std. Err. of Est. $^{\circ}C$	Mean $^{\circ}C$	Std. Dev. $^{\circ}C$	Mult. Corr. Coeff.	Std. Err. of Est. $^{\circ}C$	Temp-Means, $^{\circ}C$ $\bar{T}_J > T_J(1000)$, $41.2^{\circ}C$
1000	36.03	2.041	-	-	40.05	.932	-	-	41.47
850	27.93	2.021	.9486	.654	29.45	1.765	.9502	.581	28.27
700	15.27	1.944	.9569	.577	15.40	1.998	.9376	.735	15.87
500	-3.94	2.731	.8322	1.546	-3.23	3.206	.8485	1.794	-4.43
300	-28.17	2.059	.9394	0.721	-27.68	1.542	.8034	.970	-27.13
200	-49.39	1.664	.9586	.484	-48.98	1.458	.9572	.446	-48.17
150	-63.20	1.512	.9335	.554	-63.15	1.263	.9517	.410	-62.00
100	-78.30	1.989	.6551	1.535	-78.09	1.894	.7319	1.364	-79.23

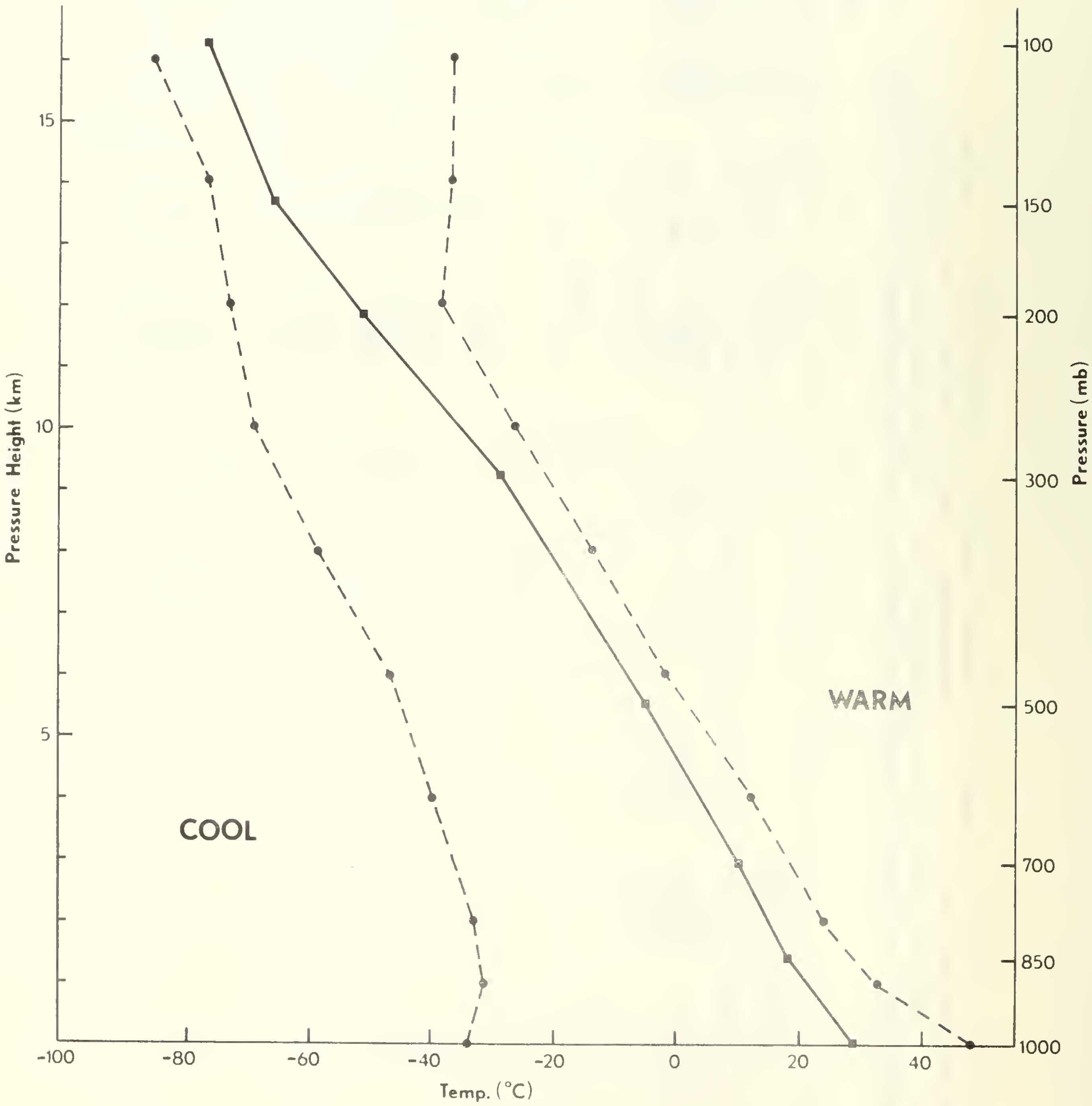

Fig. 10. Regression-generated July temperature profile (solid curve) at MAJURO corresponding to the 1% extreme-warm forcing-level temperatures T_J(Sfc) at the surface. The COOL and WARM profiles (dashed) are based on the level-by-level 1% Naval-air extremes listed in MIL-STD-210B (1973).

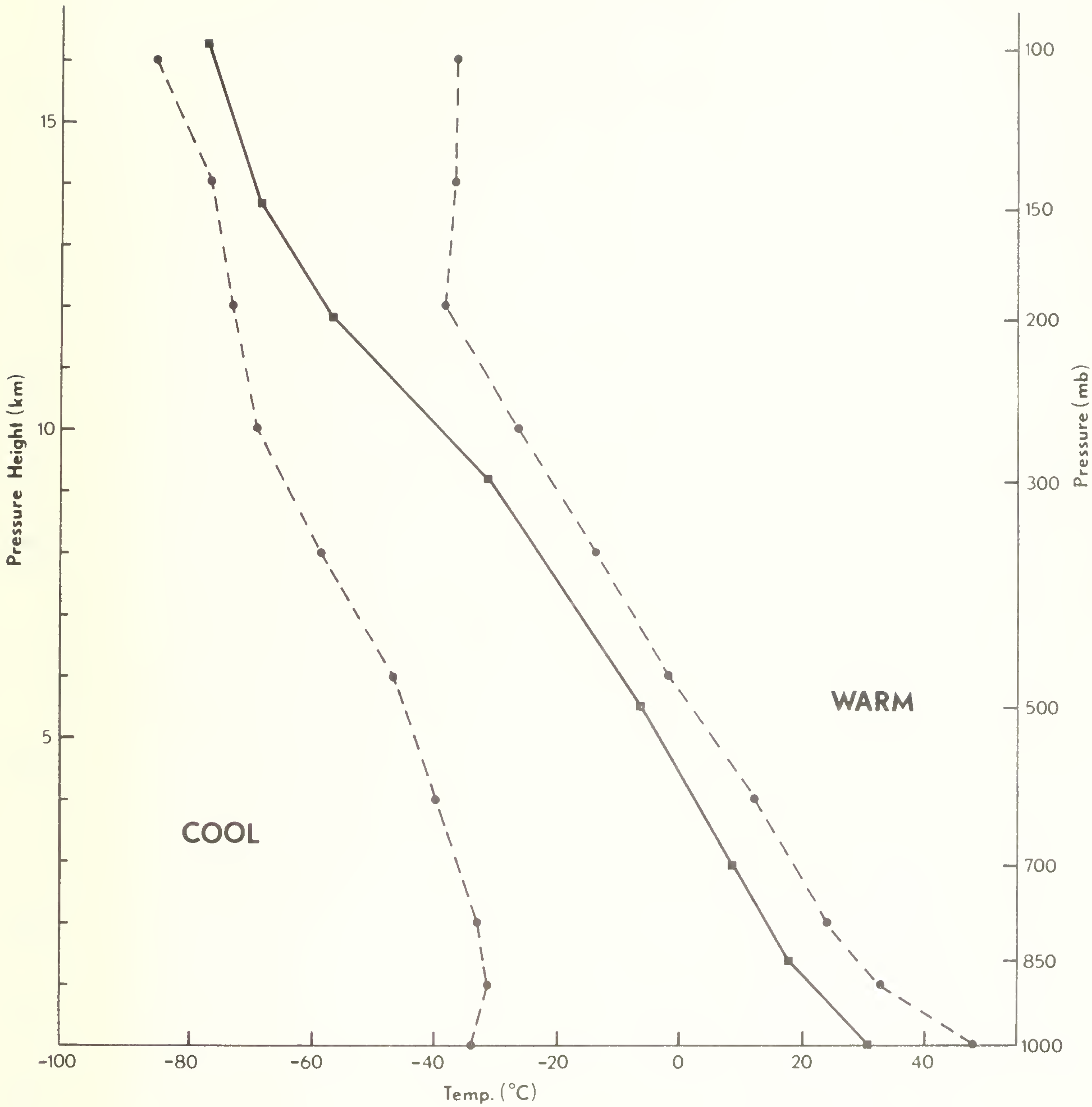

Fig. 11. Regression-generated July temperature profile (solid curve) at GAN corresponding to the 1% extreme-warm forcing-level temperatures T_J(Sfc) at the surface. The COOL and WARM profiles (dashed) are based on the level-by-level 1% Naval-air extremes listed in MIL-STD-210B (1973).

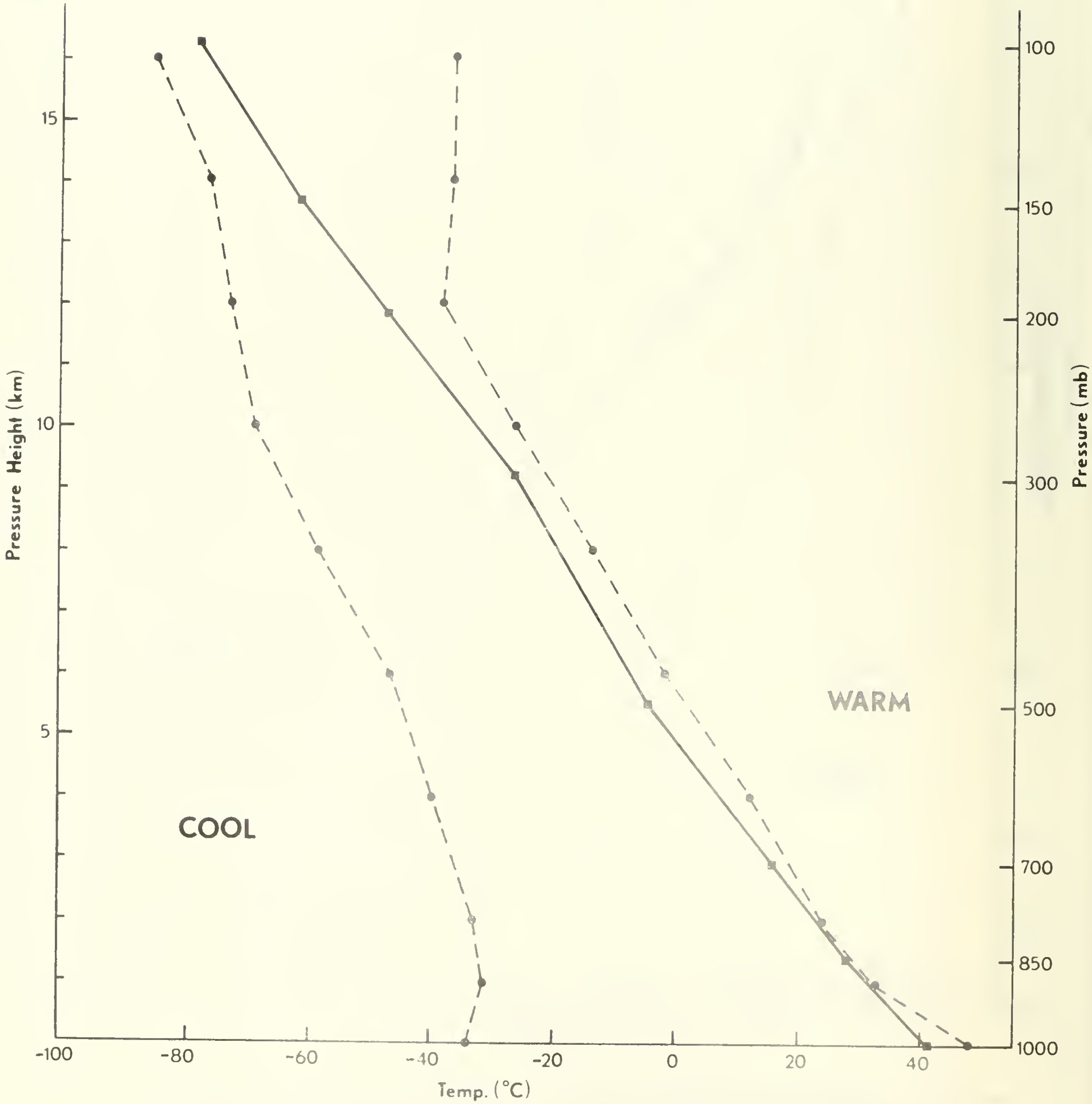

Fig. 12. Regression-generated July temperature profile (solid curve) at BAHRAIN corresponding to the 1% extreme-warm forcing-level temperatures T_J(Sfc) at the surface. The COOL and WARM profiles (dashed) are based on the level-by-level 1% Naval-air extremes listed in MIL-STD-210B (1973).

4. Conclusions

The general similarity in the regression-generated profiles from geographically-close stations having comparably close forcing-levels seems to bear out the numerical validity of the results of this study, as well as those of earlier studies in the series. It was particularly reassuring to find close agreement in the estimates of Naval-air extreme temperatures (both warm and cold) developed here and the corresponding values proposed by Crutcher (1973), and reflected also in MIL-STD-210B.

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